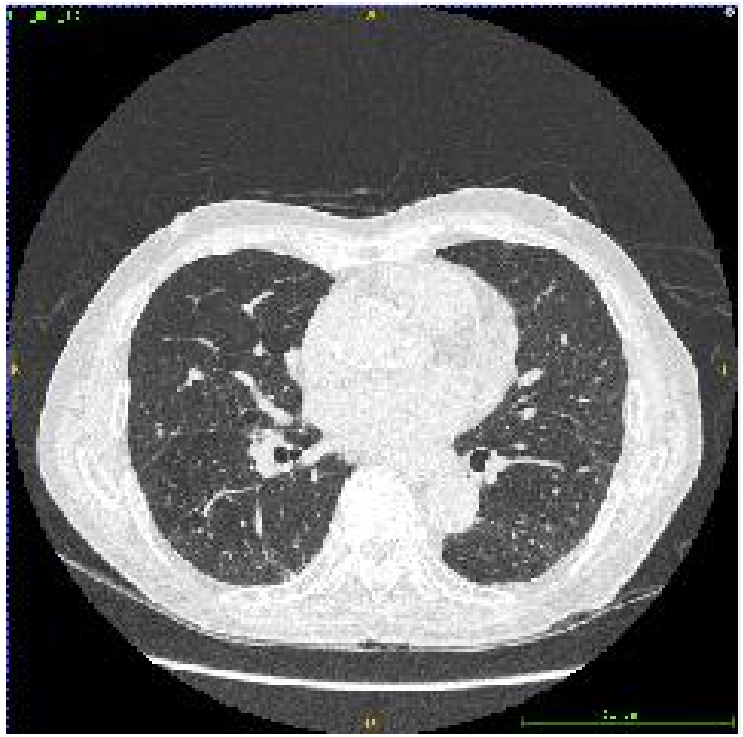
BG-Net: Boundary-Guided Network for Lung Segmentation on Clinical CT Images

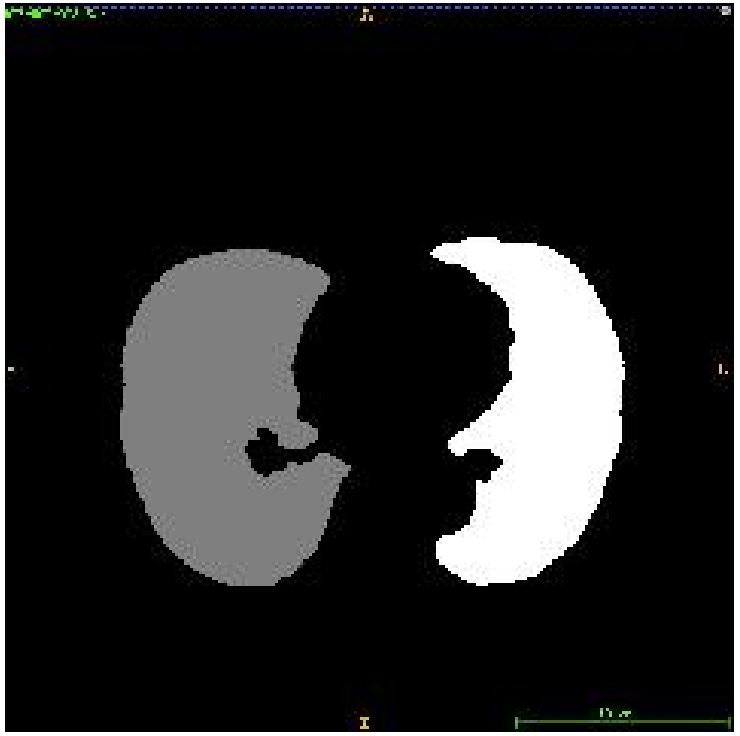
Rui Xu*†‡, Yi Wang§†‡, Tiantian Liu§†‡, Xinchen Ye*†‡, Lin Lin*†‡,
Yen-Wei Chen¶, Shoji Kido‖ and Noriyuki Tomiyama‖
*DUT-RU International School of Information Science & Engineering, Dalian University of Technology, Dalian, China
†DUT-RU Co-Research Center of Advanced ICT for Active Life, Dalian, China
‡Key Laboratory for Ubiquitous Network and Service Software of Liaoning Province, Dalian, China
§College of Software, Dalian University of Technology, Dalian, China
¶College of Information Science and Engineering, Ritsumeikan University, Shiga, Japan
‖Department of Diagnostic and Interventional Radiology, Graduate School of Medicine, Osaka University, Osaka, Japan

Background

- Quick or early diagnosis of lung diseases is crucial in clinics, especially for COVID-19 at present.
- Computer-aided diagnosis system of lung CT images.



Lung CT Image

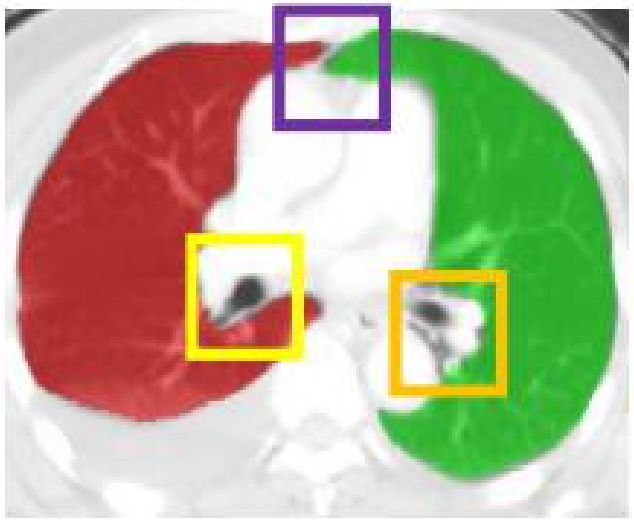


Ground Truth

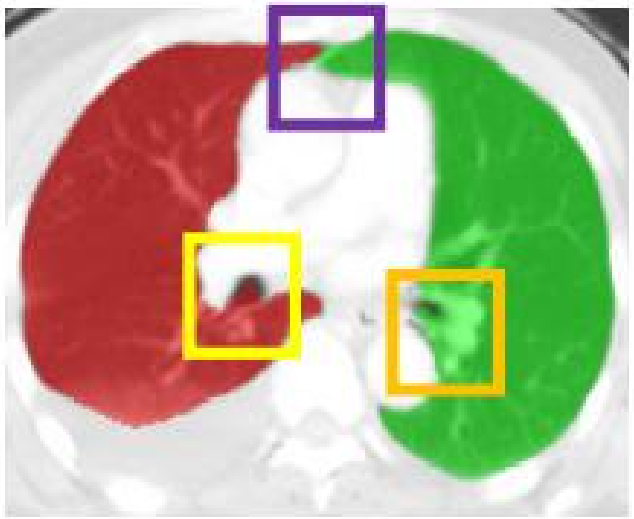
Background

- Quick or early diagnosis of lung diseases is crucial in clinics, especially for COVID-19 at present.
- Computer-aided diagnosis system of lung CT images.
- Disconnection of adjacent tips or trachea.
- Lung boundary can provide visual cues that can help radiologist to identify the lung regions

Boundary information

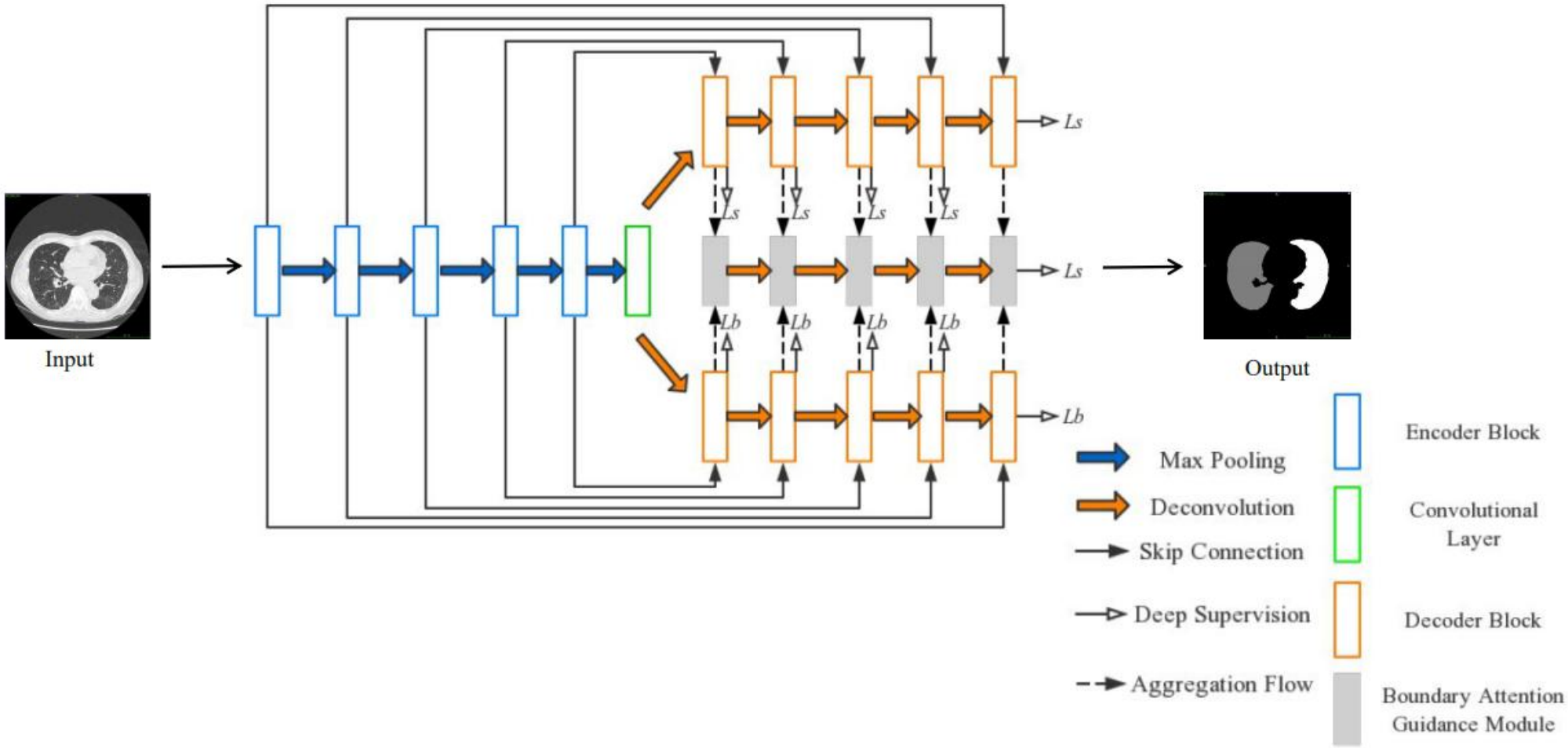


Ground Truth

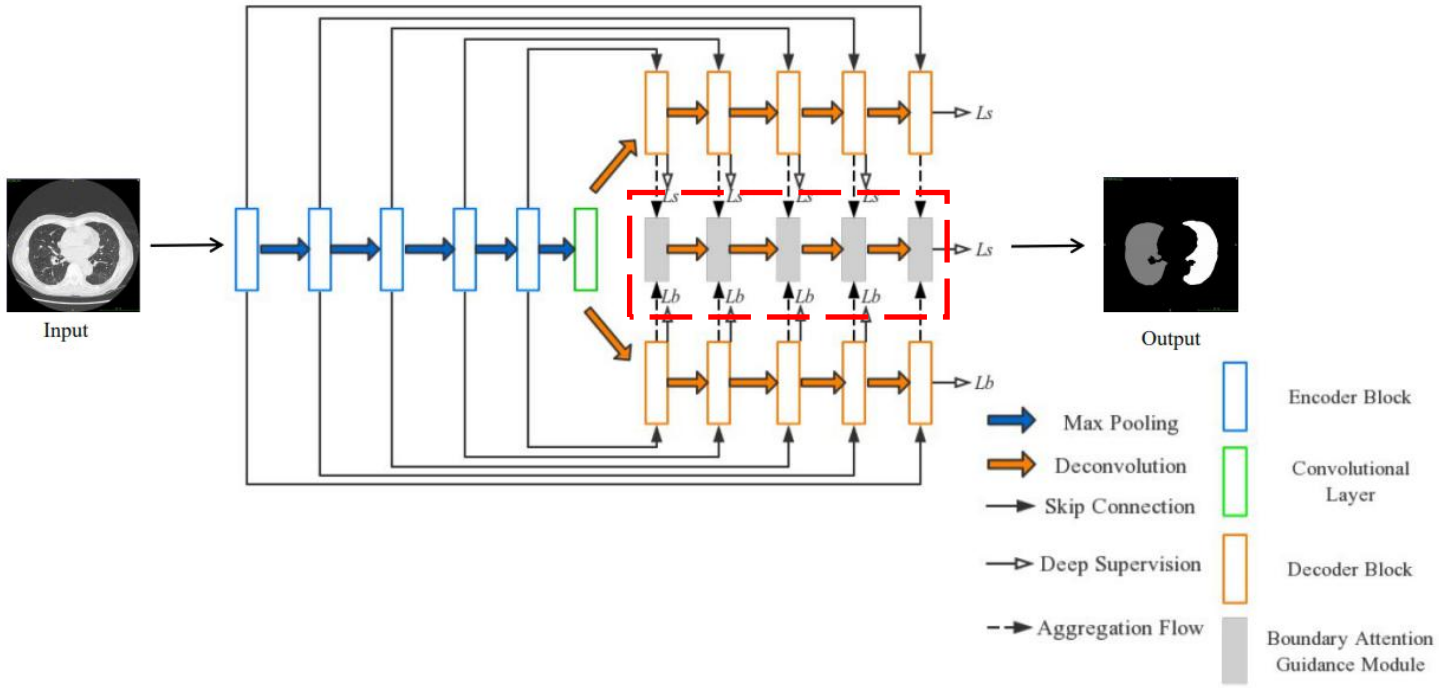


Segmentation Result

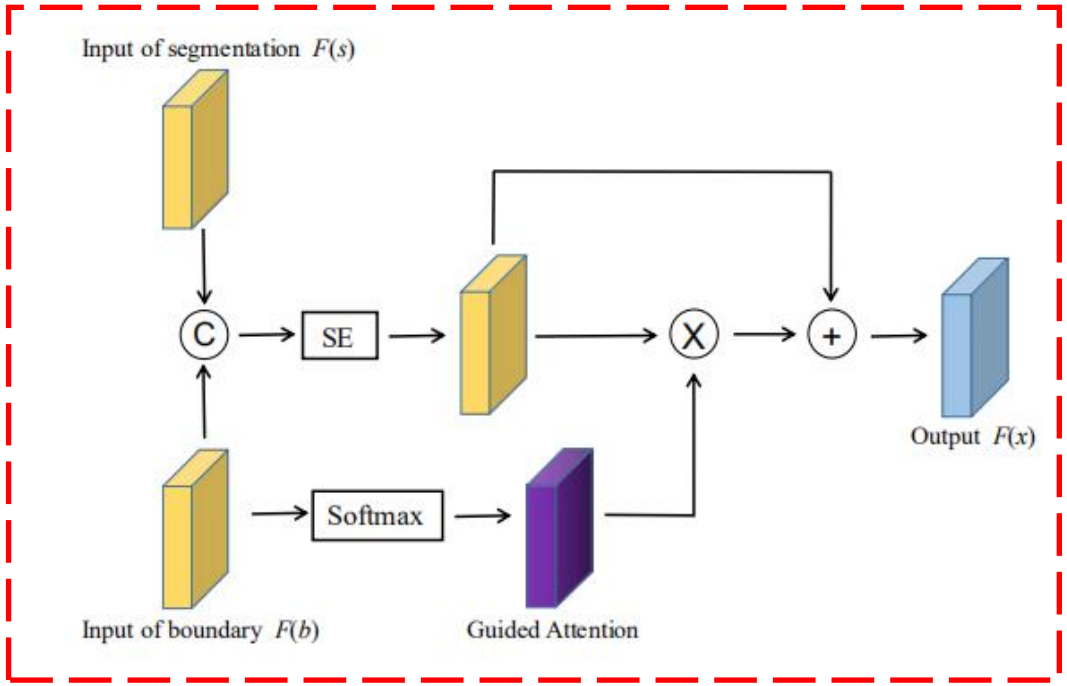
The Proposed Boundary-Guided Network



The Proposed Boundary-Guided Network



$$L = -\sum_{i=1}^{N} y^{(i)} log\, \hat{y}^{(i)} + (1 - y^{(i)}) log\, (1 - \hat{y}^{(i)})$$



Boundary Attention Guidance Module

Datasets and Evaluation Metrics

Datasets	Osaka	StructSeg	HUG	VESSEL12	COVID-19-CT-Seg
Total	217	50	108	20	20

Dice coefficient (DSC)

$$DSC = \frac{2|P \cap G|}{|P| + |G|}$$

Average surface distance (ASD)

$$ASD(Ps, Gs) = mean(\vec{ASD}(Ps, Gs), \vec{ASD}(Gs, Ps))$$

$$\vec{ASD}(Ps, Gs) = \frac{1}{|P|} \sum_{p \in Ps} \min_{g \in Gs} d(p, g)$$

Hausdorff distance (HD)

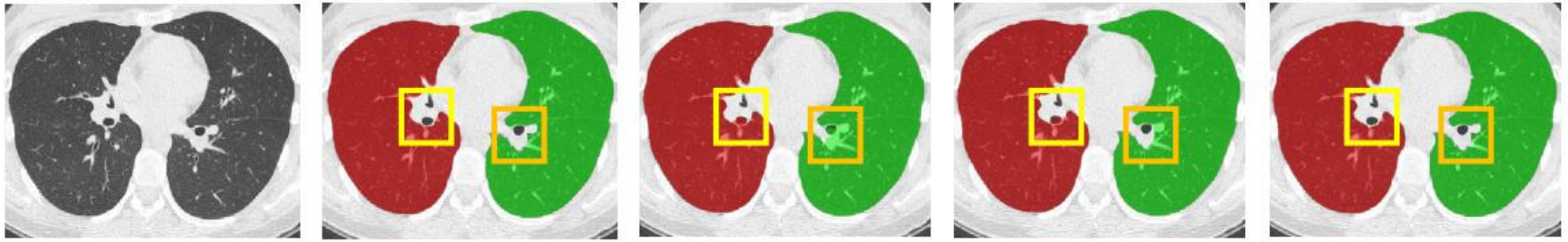
$$HD(Ps, Gs) = max(\vec{HD}(Ps, Gs), \vec{HD}(Gs, Ps))$$

$$\vec{HD}(Ps, Gs) = \max_{p \in Ps}(\min_{g \in Gs} d(p, s))$$

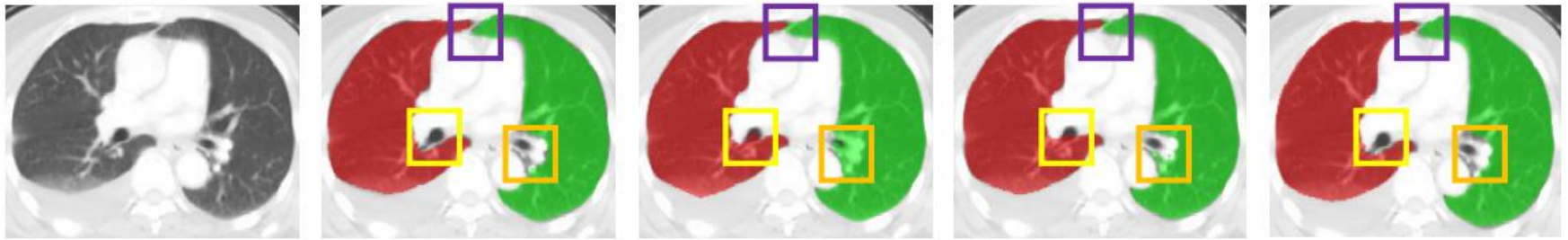
Result : Ablation Study

Dataset	Method	SB	BB	BAGM	DSC			ASD			HD		
					Whole	*Left*	*Right*	*Whole*	*Left*	*Right*	*Whole*	*Left*	*Right*
Osaka	Method-A	√			0.9824	0.9772	0.9846	0.7939	0.9321	0.7419	4.1590	4.9200	3.9795
	Method-B	√	√		0.9844	0.9814	0.9852	0.6518	0.8204	0.6396	3.0413	4.3248	3.0182
	Method-C	√	√	√	**0.9858**	**0.9825**	**0.9865**	**0.5878**	**0.6230**	**0.5728**	**2.7715**	**3.5899**	**2.7256**
StructSeg	Method-A	√			0.9619	0.9596	0.9621	0.4468	0.5350	0.3764	2.0039	3.0486	1.5731
	Method-B	√	√		0.9638	0.9598	0.9654	0.3613	0.4913	0.3500	1.4366	1.9454	1.2243
	Method-C	√	√	√	**0.9647**	**0.9612**	**0.9666**	**0.3437**	**0.3684**	**0.3414**	**1.3952**	**1.8112**	**1.1828**

Osaka



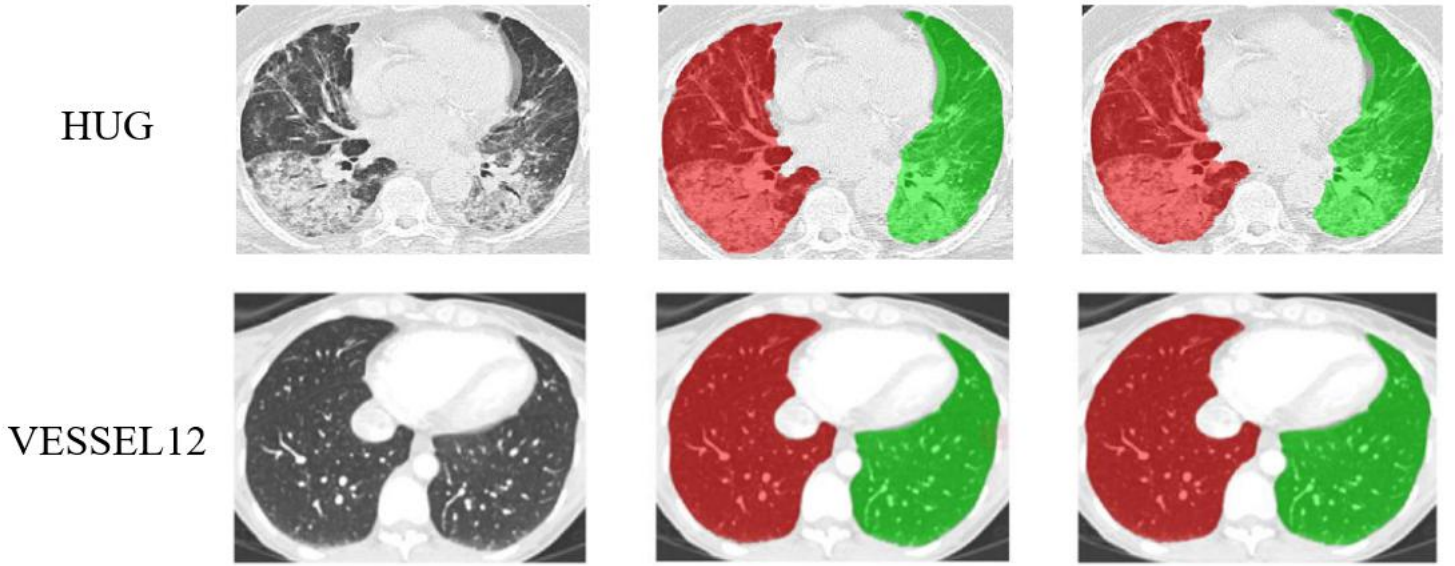
StructSeg



(a) lung CT image (b) ground truth (c) Method-A (d) Method-B (e) Method-C

Result : Comparison with the state-of-the-art methods

Dataset	Method	DSC	ASD	HD
HUG	Harrison et al.	0.9790	0.3610	-
	Jeovane et al.	0.9867	-	-
	LaLonde et al.	0.8892	-	37.1710
	Ours	**0.9889**	**0.1304**	**0.6655**
VESSEL12	Jeovane et al.	0.9919	-	-
	Soliman et al.	0.9900	-	-
	Ours	**0.9945**	**0.4981**	**1.4041**



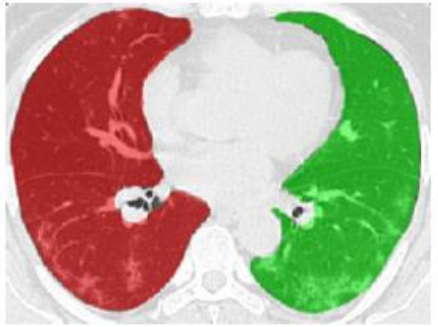
(a) lung CT image (b) ground truth (c) prediction result

Result : Comparison with the state-of-the-art methods

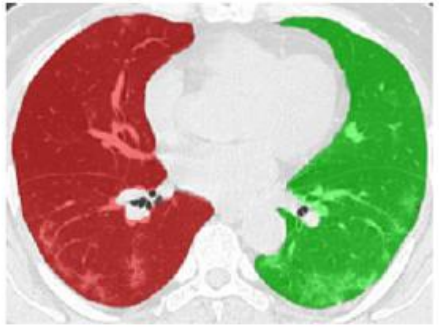
Dataset	Method	DSC		ASD		HD	
		Left	*Right*	*Left*	*Right*	*Left*	*Right*
COVID-19-CT-Seg	HED	0.8064	0.8207	11.2448	9.9281	64.1505	60.8332
	FCN	0.9233	0.9298	10.1031	9.7388	54.8521	53.5381
	U-Net	0.9481	0.9501	4.7416	4.5995	46.7094	43.7777
	Ma et al.	0.9220	0.9550	-	-	-	-
	Ours	**0.9624**	**0.9671**	**2.8405**	**1.4677**	**15.8190**	**12.5875**

COVID-19-CT-Seg

(a) lung CT image



(b) ground truth



(c) prediction result

- Even some complex boundaries can be segmented by the proposed method.
- The proposed method is less affected by the pathology of the lungs.

Conclusion

- We propose a boundary-guided network (BG-Net), which exploits the information of lung regions and the corresponding boundaries for accurate lung segmentation on clinical CT images.
- We design the boundary attention guidance modules(BAGMs) that can efficiently guide the BG-Net to learn more powerful lung segmentation features.
- We evaluate the proposed method on a private dataset and four public datasets including a COVID-19 dataset. Experimental results show that our proposed method can segment lungs more accurately and outperform several other leading methods.

Thanks For Your Attention